APPENDIX D

CONSTRUCTION QUALITY CONTROL (CQC)

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The effectiveness and long-term performance of either a permeable or impermeable barrier depends on the level of construction quality control that is implemented. This section will address the more commonly used barrier technologies in environmental applications such as slurry walls, deep soil mixing, and jetting. In addition, CQC issues for sealable-joint sheet piles will be addressed because this technique is becoming more widely used.

Slurry Walls

Steps that should be taken prior to construction include the development of a CQC plan which reflects the technical aspects of the barrier design. After the depth of the wall is specified, the plan should be geared towards the two important aspects of the wall design, conforming impermeability and wall continuity. This is carried out through a series of CQC tests conducted prior to wall construction to accurately provide the specifications of the slurry makeup and the backfill mix, specifically, its compatibility with contaminants, its effect with temperature, and achieving the desired permeability. It should address remedial techniques for substandard construction practices and for any other problems that might arise during implementation.

Listed below are some quality control considerations and guidelines for slurry walls modified after Bell and Sisley (1992).

QC of Slurry/Backfill Mix

- Check the calibration of all measuring devices.
- Measure and record quantities of each ingredient as metered by the batch plant.
- Compare batch measurement totals with material inventory usage. Record comparisons each shift or more frequently. Investigate disparities.
- Measure and record specific gravity of each slurry mix component.
- Measure and record viscosity/slump as appropriate.
- Measure and record filtrate loss.
- Measure and record pH.
- Measure and record gradation of backfill.
- Measure and record permeability of backfill.
- Document observations and comments on sequence of combining ingredients and thoroughness of mixing. Record times when changes are observed.
- Properties mentioned in the fourth through seventh items should be measured prior to the addition of cement to a bentonite slurry in cement-bentonite slurries.
- Measure and record sand content for cement-bentonite slurry walls.
- Allow bentonite to fully hydrate prior to the addition of cement for a cement-bentonite slurry.

QC During Trenching and Slurry Placement

- Record time elapsed between batching and placement in wall, rate of slurry delivery and indicate location (station) in wall where batches are placed.
- Measure and record depth, width, and wall continuity at frequent intervals.

- Measure and record trench verticality by measuring verticality of excavation equipment.
- Determine trench continuity by sweeping trench bottom with backhoe bucket or a vertical probe.
- Determine the penetration of the trench into a natural aquiclude during key excavation.
- Measure and record depth to top of backfill at time of placement and after setup.
- Document observations and comments on caving, squeezing, sloughing, or other ground movements.
- Obtain samples of slurry backfill prior to setup from mid to lower portions of wall.
- Mold slurry samples for laboratory testing. Avoid excessive mixing. For slurries that shrink or bleed, molds should be more than 2 diameters long.
- Store and transport samples to avoid vibration and exposure to excessive heat or cold.
- Install guide casings for subsequent drilling and sampling in deep or narrow walls.

QC During and After Setup/Hardening

- Visually inspect backfilled trench for indications of variability, cracking, excessive drying, contamination, dilution, bleeding, subsidence, disturbance, etc., until material has hardened and cover is in place.
- Observe installation of construction joints at shift startup and after delays during installation.
- Drill and sample cutoff materials for visual inspection and laboratory testing. Use drilling and sampling methods compatible with wall strength and sensitivity to minimize sample disturbance. By specifying in detail the drilling, sampling, and testing methods, controversy as to the representativeness of results can be minimized because the minimum acceptable results apply only to those obtained by the specified methods. The methods used can also be improper or controversial, particularly in weak or fragile materials. Therefore all details of drilling, sampling, sample handling, transport, and storage must be carefully evaluated in the QC program, particularly when results indicate marginal or inadequate strength or hydraulic conductivity.
- Packer tests performed on the trial cutoff walls were not completely successful. In narrow walls and weak materials, their results are questionable.

QC During Laboratory Testing

- Moisture content and dry density results from molded and core samples are useful in evaluating wall uniformity and changes that occur in the mix after batching.
- Unconfined compressive strength tests were considered appropriate for evaluating wall strengths.
- The measurement of hydraulic conductivity of nearly impermeable materials requires quality apparatus, skillful care in sample preparation, testing, recording, and presenting results.

Jet Grouting and Deep Soil Mixing

As with slurry walls, the two important aspects to consider when developing a CQC plan for impermeable walls emplaced using jet grouting or soil mixing techniques, are maintaining wall continuity and maintaining the desired impermeability. Because both of these grouting techniques create walls through the successive emplacement of soilcrete columns, CQC issues will be addressed together.

QC Prior to Grouting

Obtain soil samples from test site for compatibility testing of the resulting soil-grout mixture. This will determine the susceptibility to permeation by chemical contaminants. The permeability of the soil matrix and the available void space will dictate the water/cement ratio of the grout, grout pressures, and hole spacing used. Wall thickness will determine the spacing of the grout hole array. The quality of the grout mixture can be determined by pouring a sample into a tray 1-inch deep and leaving it to set overnight. Break the sample open the next day and observe a vertical section. If banding is present within the section, it is an indication of poor mixing. It is also suggested that a pump test be performed at the field site to determine baseline conditions for later comparisons.

QC During/After Construction

Because the equipment used in jet grouting is highly computerized, a trained and experienced operator is required to monitor the process. During the injection, readouts of flowrates, injected quantities, and materials used are generated, and based on data interpretation, the process can be modified to those desired. Some other important construction controls include the following:

- Determine the water/cement ratio in the field by measuring the specific gravity of the grout and relating it to published tables.
- Measure the permeability by making a hole in a completed section of the wall, at the farthest distance away from the grout hole, and pump water into it at a constant rate. Drill observation holes outside the limits of the barrier and monitor the response to the pumping to determine the permeability.
- Install piezometers upstream and downstream of the barrier to monitor differences in water levels.
- Core the barrier to determine the amount of grout that has been injected into the soil matrix and the effectiveness of the wall.
- Monitor grouting pressures for changes in subsurface conditions.

Sealable-Joint Sheet Piles

The following construction quality control issues presented for sealable-joint sheet piles are taken from the "Waterloo Barrier™ Pile Driving and Joint Sealing General Specifications" (Jowett, 1996).

Part 1- General

1.03 Submittals

Submit the following items for review by the Engineer:

1. Certification: Provide documentation of agreement with a Waterloo Barrier Inc. licensed installer for provision of quality control service for the sheet pile installation and to complete joint sealing.

2. Pile Driving Plan, which outlines detailed pile placement, splicing requirements and details, method to achieve verticality within 1%, QC measures, joint preparation prior to sealing, and grout materials, mixing, and placement.

3. Mill test documentation for piling to be used on project.

4. Manufacturer's data that indicate the structural properties of piling sections(s) to be used, including I, S, moment capacity, thickness, and width/depth dimensions.

5. Proposed welding procedures and certification of welders.

1.04 Coordination

Notify the engineer at least 5 days prior to beginning pile installation operations at any location. This will not relieve the contractor of his responsibilities for performing the work in accordance with these specifications and contract Drawings.

1.05 Quality Control

A. The Quality Assurance/Quality Control (QA/QC) program and joint sealing is to be completed by a Waterloo Barrier Inc. licensed installer.

B. Horizontal Alignment and Plumbness Tolerances: The maximum permissible horizontal tolerance in pile installation will be a deviation of not more than 6 inches (150 mm) from the plan location indicated on the Drawings.

PART 2- PRODUCTS

2.01 Sheet Piles

A. Provide poling as manufactured by Canadian Metal Rolling Mills in Cambridge, Ontario or other approved manufacturer under license from Waterloo Barrier, Inc.

B. A foot plate will be welded to the base of each female joint of the sealable sheet piling to prevent soil from entering the joint as the pile is being driven into the ground. The fabrication and attachment of the foot plate will be the responsibility of the Site Contractor. Exact dimensions of the foot plate will be based on the final rolled sheet piles. The Contractor will make the necessary fabrication arrangement to assure manufacture of the plates does not delay the sheet pile installation.

C. If the contractor chooses to drive sheet piles in doubles, a cone shall be employed to prevent soil from entering the mated (center) joint. The contractor will be responsible for the

fabrication and installation of the cone for each paired sheet pile set. Specific dimensions of the cones will be based on actual rolled sheets. Foot plates will be welded to the base of the female joint of the paired set as described in the preceding paragraph.

D. Sheet pile containment wall depths are as indicated on the Plans and Specifications.

PART 3 - EXECUTION

3.01 Sheet Piles Installation

A. Handling Sheet Piles

1. Lift in a manner which will not cause excessive bending stresses.

2. Do not damage sheet piles in either handling or installation operations.

3. The joint of each sheet pile will be visually inspected by the contractor prior to driving. Any foreign material will be removed and damaged joints and/or sheet piles will be rejected.

4. Replace or repair sheet piles which are damaged during driving.

B. Location and Tolerances

1. Drive piles vertically and in correct alignment so that the top of the wall lies on a straight line and ensure a proper interlocking throughout the entire length of the piles.

2. Sheet pile locations on the drawings are approximate and will be field located when appropriate and when approved by the engineer.

3. Deviation in horizontal alignment will not exceed 10 degrees at each joint.

4. The maximum permissible vertical tolerance (plumbness) in pile installation will not be greater than a deviation of 1/16 inch per 1 foot vertical. The integrity of the interlock between adjacent piles will be verified by flushing the joint. Joint inspection and flushing will be performed by the Quality Control Engineer.

C. Set Up Sheet Piles

1. Drive piles with equipment suitable for the conditions encountered. The method and equipment selected will deliver the necessary energy to drive the piling to the design depths as shown on the drawings and minimize damage to each end of piling and adjacent interlocks. Suitable procedures must be employed to prevent damage to pile tops and joints.

2. Prevent and correct any tendency of sheet piles to bend, twist or rotate, and to pull out of interlock. The integrity of each pile and interlocked joint must be maintained during and after driving.

3. Top of pile at elevation of cut-off will be within 2 inches (50 mm) of the specified alignment. Manipulation of piles to force them into position will not be permitted. Piles will be checked for heave. Piles found to have heaved will be redriven to the required point elevation.

4. Piles damaged or driven outside the above tolerances will be replaced. Any sheet pile ruptured in the interlock or otherwise damaged during driving will be immediately pulled and replaced.

5. Piles will be driven not deeper than 1 foot (300 mm) of the specified depths for each location. The contractor shall take necessary precautions to assure adjacent piles do not penetrate deeper during pile installation.

6. Pull any sheet piling that are known to have pulled out of interlock or are suspected of having tip or interlock damage, as determined by the Quality Control Engineer, and pull for visual inspection before proceeding further.

7. Splicing is permitted is shown on the drawings or as approved by the engineer.

8. Make splices using a full penetration weld or as otherwise directed by the engineer for structural purposes.

3.02 Joint Sealing

A. All sheet pile joints are to be sealed. Joint sealing is to be performed by a Waterloo Barrier, Inc. licensed installer.

B. Joint sealing will not be performed adjacent to sheet pile installation within a radius of the length of one sheet plus 10 feet (3 m) from the sheet piling installation point.

C. After sheet piling has been installed in the ground, all sealable cavities will be checked by probing and flushing of the joints with pressurized water to remove any remaining soil material.

D. During the flushing, a hose or pipe will be inserted into the sealable cavity and advanced downward. The hose will allow soil particles to travel up and out of the cavity. Removed water and soil will be handled as specified in Project documents.

E. The flushing operation will be considered complete when the hose has been passed to the base of the sealable cavity and the water escaping from the top of the hole is relatively clean. The flushing hose may then be removed from the cavity.

F. A tremie hose or tube for pressure injection of the sealant will be inserted into the sealable cavity. When the tube has reached the bottom of the hole, sealant injection will begin. The hose will be withdrawn progressively up the hole as the sealant fills the space below. Keep tremie nozzle at least 6 inches (150 mm) below rising surface of sealant.

G. The speed at which the injection tube is withdrawn must be carefully regulated to prevent trapping water or air bubbles with the sealant and to ensure there is adequate sealant to fill the cavity.

H. The sealant used must be capable of penetrating into the potential leak paths, and have a low permeability to water. The sealant selected must also be resistant to chemical interaction and degradation when in contact with contaminated groundwater. The sealant will have a hydraulic conductivity of less than or equal to 1 x 10-7 cm/sec.

3.03 Records

A. Provide accurate records of each sheet pile installed. Submitted records will include the following information:

- Pile identification number
- Date and time of driving
- Model of hammer and energy rating
- Elevation at top of pile
- Length of sheet pile in the ground when driving is complete
- Rate of penetration in ft/minute
- Detailed remarks concerning alignment, obstructions, etc.
- Plumbness record of each sheet pile installed
- Joint flushing record for each joint installed.

B. Mark waterproof identification number clearly visible on each sheet pile, within two feet (600 mm) of the top, before driving is initiated.

C. Spray paint all sheet piles rejected from the work for any reason, at the time of rejection, with the letter “X” within three feet (1 m) of both ends.

D. Provide accurate sealant installation records. Submitted records will include the following information:

- Joint identification number
- Date and time of sealing operation
- List of equipment used during the installation
- Volume of sealant required to seal each joint.

3.04 Rejection

If rejected from the work because of deviation from location, plumbness requirement excessive bending, twisting, or pulling out of interlock, or other reasons, take suitable corrective action at no additional cost to the owner. Suitable action includes extracting, and furnishing and driving of replacement sheet piles, so that all sheet piles installed meet the requirements of this specification.